EPA
United States
Environmental Protection
Agency

Reference Condition Approach: Advances Since 2000

Goal: Provide key considerations on how to develop numeric criteria based on a reference condition and recent applications

Outline

- Background
- Definition and application
- Site selection and classification
- Key concepts when using a reference condition approach
- Examples of successful applications of a reference condition approach

Background

- Adapted from the biocriteria effort for nutrient criteria derivation
- Highly variable application
  - Screening procedures for reference site selection
  - Selection of percentile
  - Linkage to designated uses or refined management goal
- Defined differently over time…

Defining "Reference Condition"

- Types of reference conditions (Stoddard et al. 2006, NLA paper):
  - Minimally disturbed condition
  - Historical condition
  - Least disturbed condition

- Working definition: In general, sites should be selected that reflect our management goal.
  - Supporting designated uses

Reference Condition Approach

- Scientifically defensible approach for deriving numeric nutrient criteria
- Spatial and temporal applications:
  - Spatial: Identifying reference waters in a region
  - Temporal: Identifying reference time periods in a site
- Physical, landscape, biological screens used, for example:
  - Land cover
  - Habitat conditions
  - Biological assessment endpoints

Selecting Reference Sites

- Ensure sites selected accurately reflect the desired ecological condition or designated use support.
- Establish site screening requirements to ensure reference site quality.
  - Landscape development intensity index score
  - Biological condition index
  - Impairment status
  - Presence of point source dischargers
- Monitoring data are used to show how each reference site's waters are supporting designated uses.

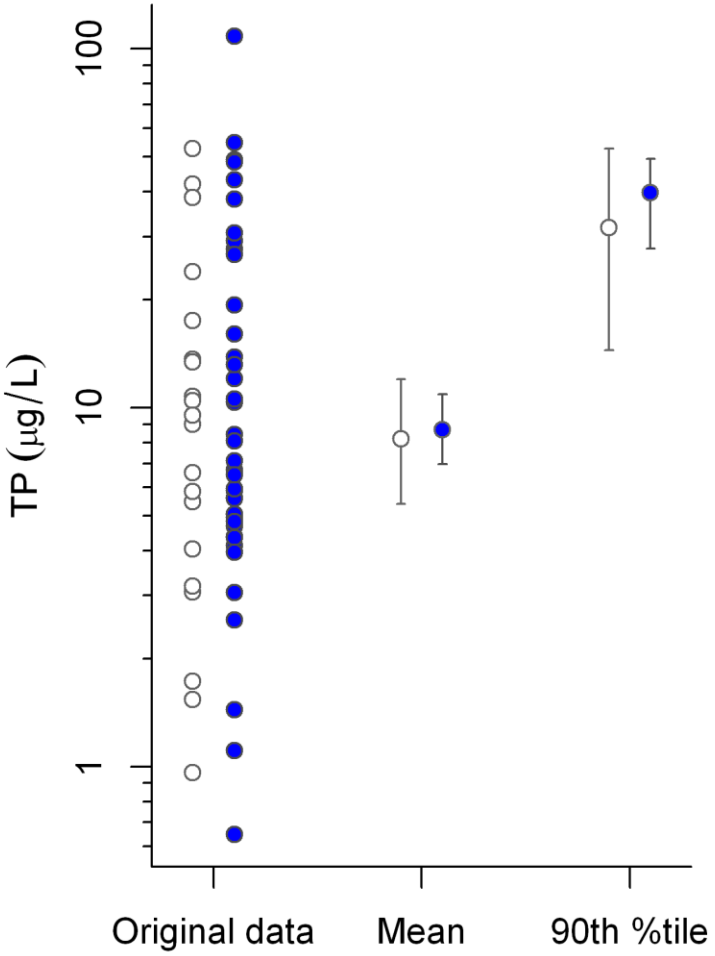
Considering Data Quantity

The quantity of data should enable:

- Capturing variability across space/time (ideal case)
- Spatial/temporal representativeness
  - Site-specific – Need considerable representation over time
  - Regional – Need considerable representation over space

Considering Data Quantity

- Consider the confidence with which different aspects of the reference distribution can be estimated.
- Confidence in estimated percentiles depends on the number of samples (i.e., reference sites) and the percentile that is estimated.
  - Percentiles close to the edge of the distribution are estimated with less confidence than percentiles close to the mean.
  - The fewer the samples, the less confidence.



Considering Data Quality

Elements of data quality important for criteria derivation:

- Ensuring data are verified and validated
- Having associated metadata, so data can be traced to a sampling site, date, and time
- Ensuring sample integrity was maintained
- Using approved EPA/state sample collection and laboratory analysis methods
- Sufficient use of quality control measures in the laboratory
- Records of instrument calibration and verification of performance

Data Requirements: What Should Your Final Reference Data Set Look Like?

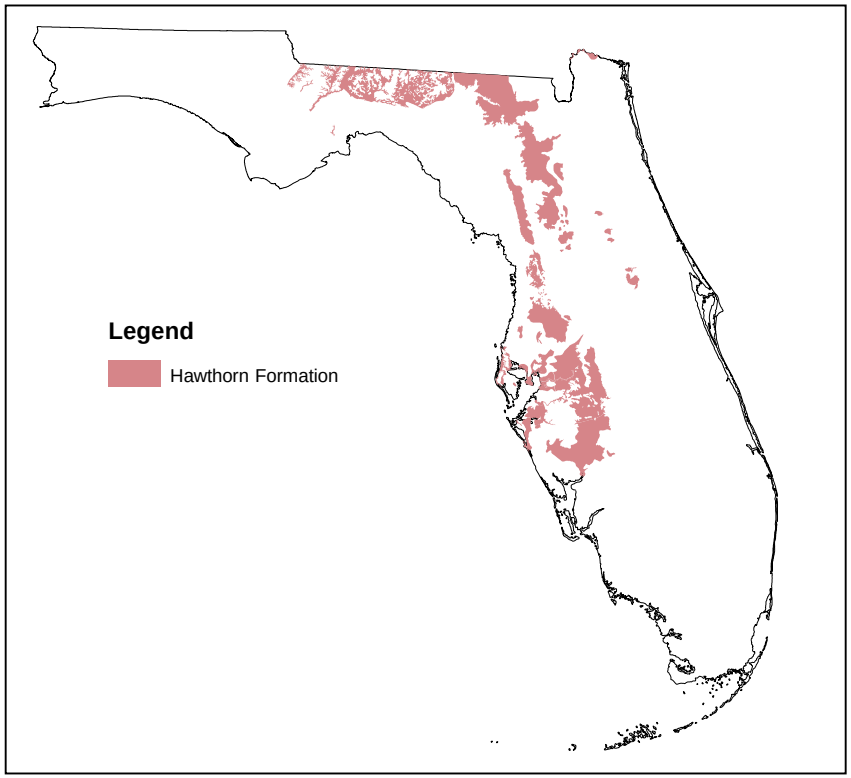
Reference site quality:

- Selecting the best of what is available – Application of screens for disturbance, such as trends in biological endpoints, landscape development intensity, and other indications of human impact
- Using the data you have available, but still ensuring designated use support – application of screens for the above and also 303(d) impairment listings

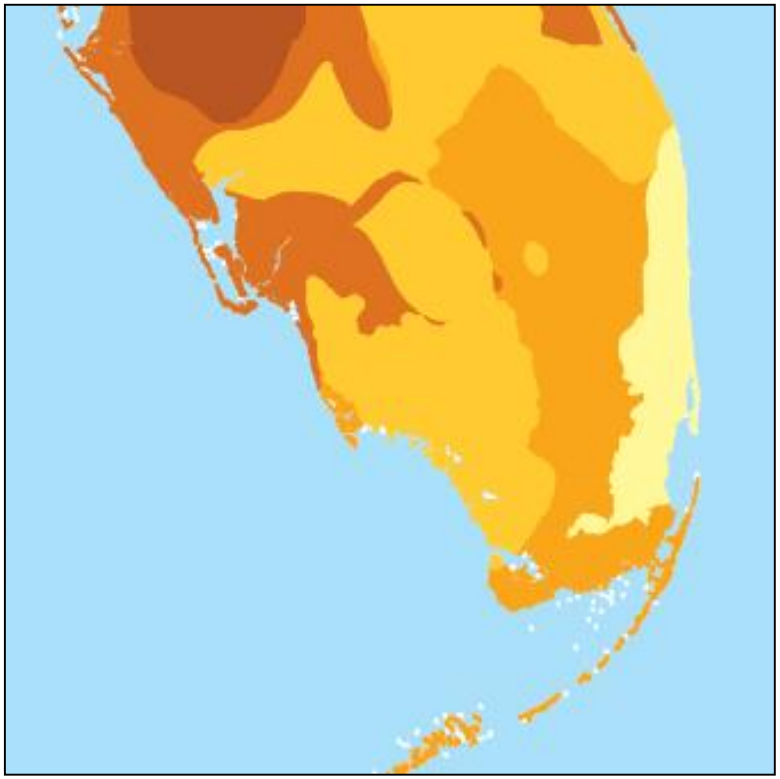
Classification of Reference Sites

- Classification of water segments and reference sites ensures water quality expectations are appropriately represented for different types of sites.
- Classification factors (e.g., geological, hydrological, chemical)
- Examples:
  - Streams
  - Estuarine and coastal waters

Classification by Geological Factors

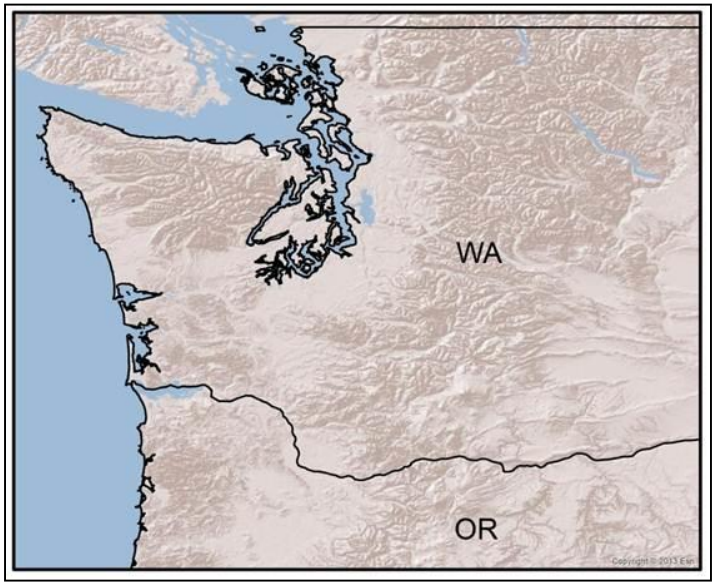


Distribution of Hawthorn Formation (elevated phosphorus)

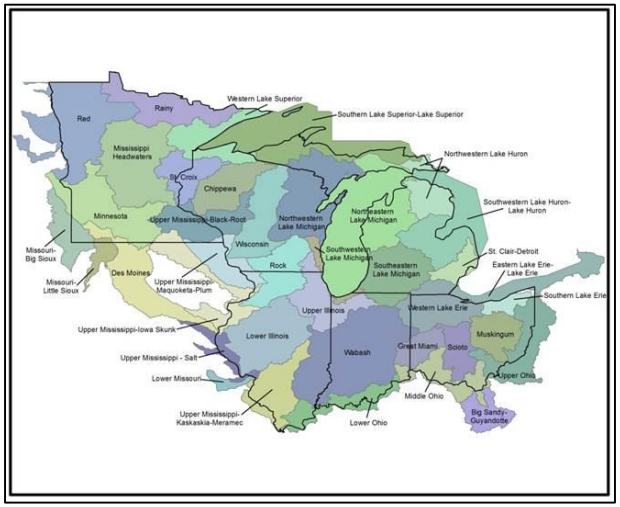


Mean values of bed-sediment phosphorus concentration within geologic map units

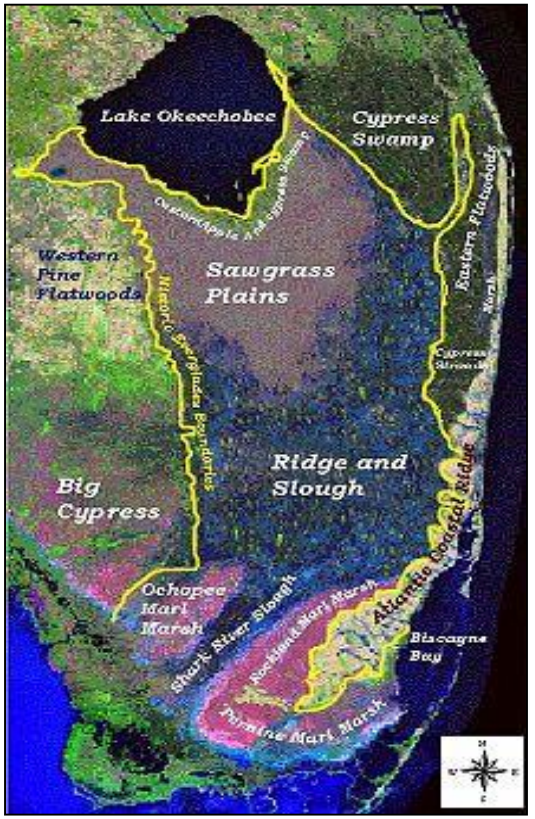
Classification of Hydrological and Ecological Factors



Elevation

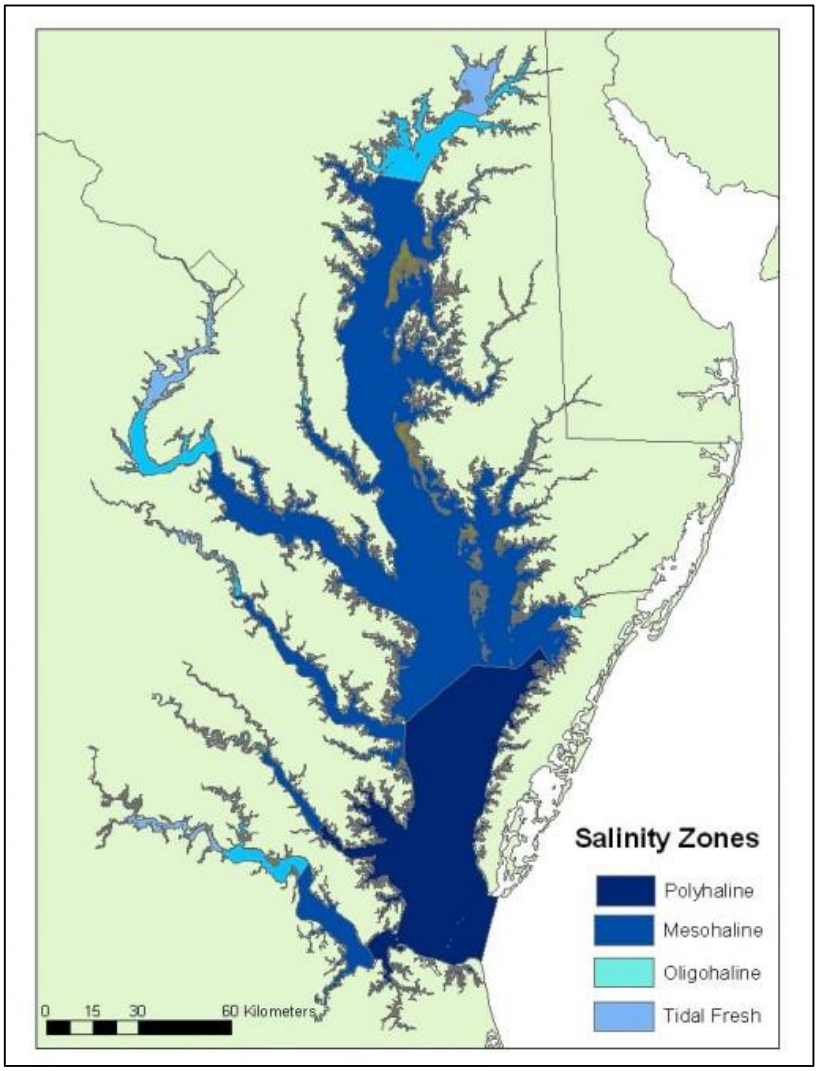


HUC-4 watersheds

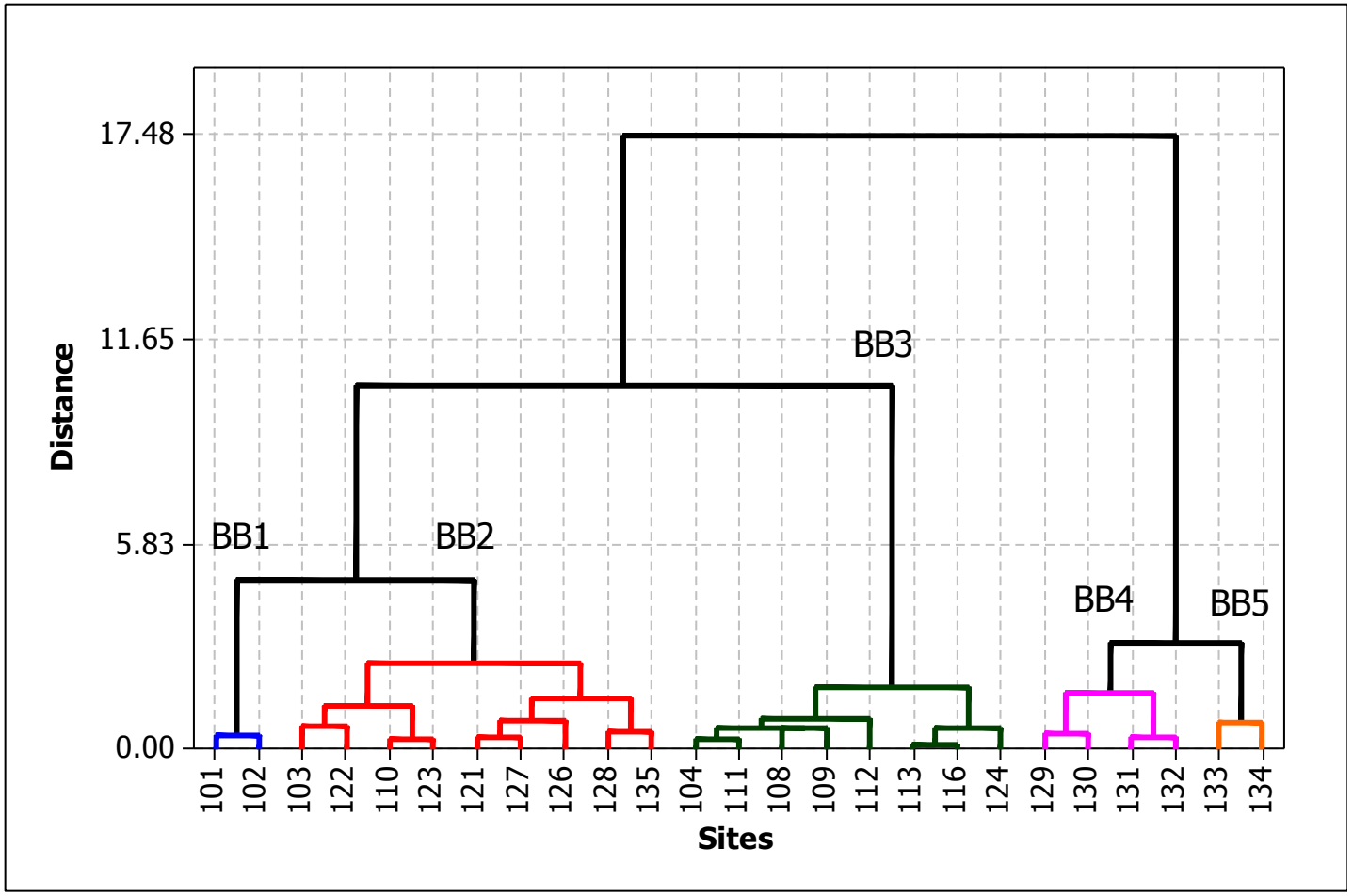


Landscape types

Classification by Chemical Factors

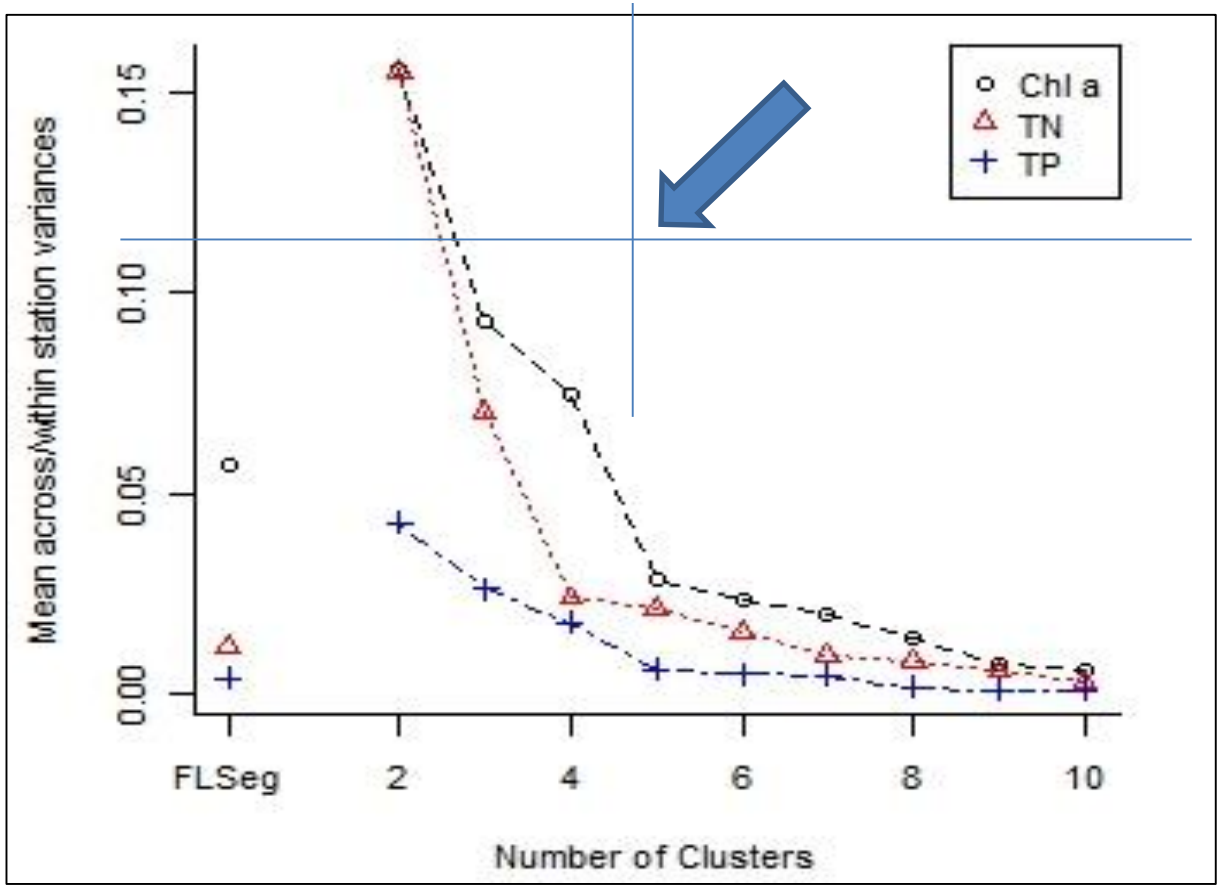


Classification by Chemical Factors

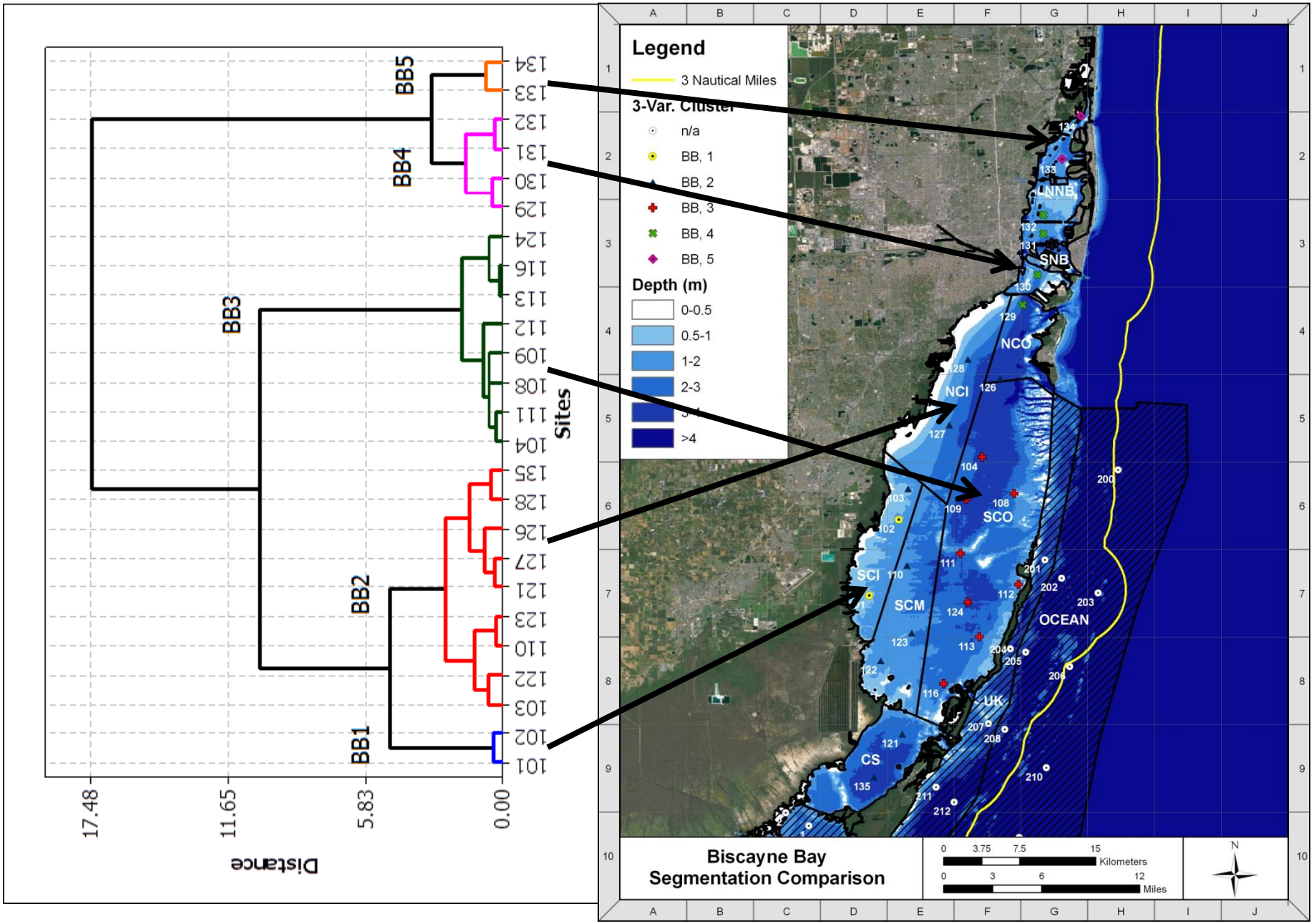


3-variable (TN, TP, and chl *a*) cluster analysis dendrogram for Biscayne Bay. Distance between clusters defined as Euclidean distance between standardized values of each variable.

Classification by Chemical Analysis



Ratio of mean across-site variance to mean within-site variance results from 3-variable cluster analysis for Biscayne Bay


BB5
BB4
BB3
BB2
BB1
Sites
Distance
17.48
11.65
5.83
0.00
Legend
3 Nautical Miles
3-Var. Cluster
n/a
BB, 1
BB, 2
BB, 3
BB, 4
BB, 5
Depth (m)
0-0.5
0.5-1
1-2
2-3
>4
UNNB
SNB
NCO
NCI
SCO
SCI
SCM
OCEAN
UK
CS
Biscayne Bay
Segmentation Comparison
0 3.75 7.5 15 Kilometers
0 3 6 12 Miles
N

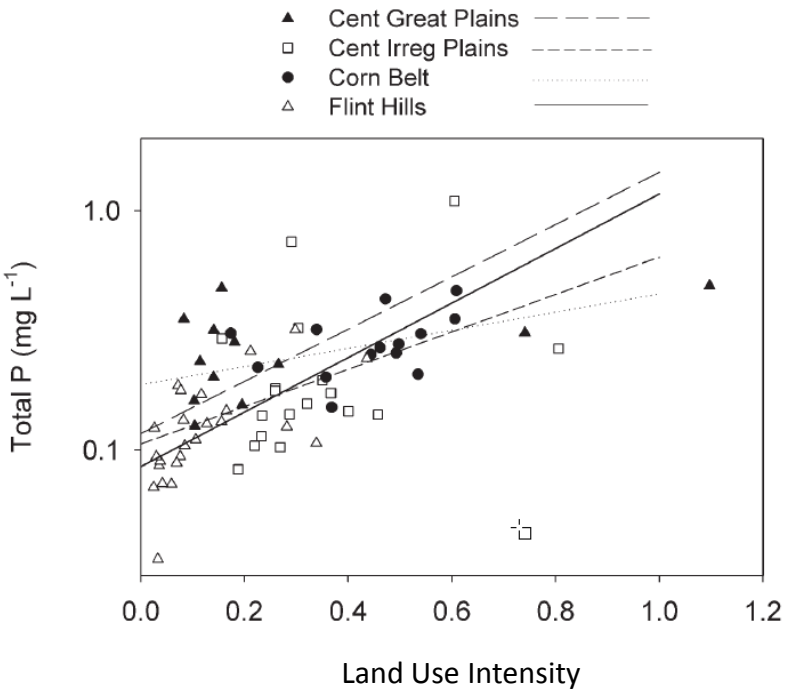
Key Concepts

- Finding sufficient reference sites:
  - What to do when you have a lack of reference sites?
- Selecting a defensible percentile:
  - Is there a magic algorithm?
  - Is there supporting scientific documentation?

Finding Sufficient Reference Sites

What if there are too few sites?

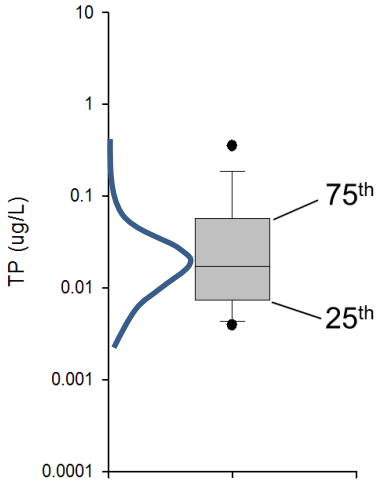
- Reference in time vs. space
- Paleolimnology
- Modeled reference condition



Source: Adapted from Dodds and Oakes (2004)

Selecting a Defensible Percentile

- Factors that might influence your decision include:
  - Quantity of reference sites
  - Condition of reference sites
  - Quantity of data based on quality screens
  - Statistical estimates of uncertainties
- Percentile selected must be protective of designated use
  - Typically 75th to 90th



Selecting a Defensible Percentile

- Also based on statistical reasoning
- For a small data set with greater heterogeneity, choose a lower percentile; for a large data set with greater homogeneity, choose a higher percentile
- Ties into assessment endpoint selection
  - Support your percentile choice with scientific literature and other available information

Reference Period Approach

- Approach to consider for a specific waterbody when:
  - There are insufficient regional reference waters
  - Current conditions might not meet reference criteria
  - Data exists from historic conditions that justifiably met reference criteria
- Need temporal screens:
  - For example:
    - Demonstrated attainment of other criteria during that time period
    - No evidence of adverse nutrient impacts
    - Pre-discharges
    - Trend data available support temporal reference

Example 1: Reference Period Approach in Estuaries

- Coastal lagoon estuary
- Minimally disturbed condition
  - No 303(d) listings for nutrients or dissolved oxygen
- Long-term data set available
  - Spatial and temporal representativeness

Example 1: Reference Period Approach in Estuaries (continuation)

- All data available from 1974–2009 were reviewed
  - No nutrient-related impairments were identified
  - Nutrient assessment endpoints were evaluated
  - Data screening is not needed
- Numeric nutrient criteria were calculated at the 90th percentile of annual geometric means
  - Water quality from the reference time period is likely protective of the designated uses

Example 2: Reference Period Approach in Coastal Waters

- Three regions (Tomlinson et al. 2004) used data out to 4 nautical miles.
- Satellite remote sensing provided extensive spatial and temporal coverage.
- Chlorophyll-a endpoint: a strong, reliable indicator of harmful biological change.

Example 2: Reference Period Approach in Coastal Waters (continuation)

EPA conducted a review of water quality information to arrive at a final reference data set:

- Reviewed 303(d) listings for nutrients, chlorophyll-a, and dissolved oxygen
- Removed segments adjacent to 303(d)-listed estuarine segments
- Consulted available scientific literature
- Evaluated satellite data trends in chlorophyll-a from 1998 to 2009

Example 2: Reference Period Approach in Coastal Waters (continuation)

Calculation of Numeric Nutrient Criteria

- Derived annual geometric mean chlorophyll-a criteria at the 90th percentile of all annual geometric means of the screened data from 1998 to 2009, including and excluding *Karenia brevis*
- Frequency and duration of 1 in 3 years

Other Examples: Reference Condition Approach in Streams

Reference sites were selected using the following screening tools:

- Macroinvertebrate index values
- Were not listed on 303(d)
- Land use intensity in riparian buffer and watershed
- NO_3 < 0.35 mg/L (considered to be an indicator for groundwater sources of nutrients)

Other Examples: Reference Condition Approach in Wadeable Streams

The reference distribution was used as a line of evidence for setting the criteria values, among other approaches.

- Nutrient concentration data were compiled for each ecoregion.
- A percentile of 75 and up was chosen depending on data availability and ecosystem characteristics.
- When/if the data show that reference sites regularly manifest greater concentrations than the regional criterion, site-specific criteria are considered within the reference range of acceptable concentrations.

Lessons Learned

- Definition of *reference condition* varies; however in all cases:
  - Reference conditions should support designated uses
  - It need not mean pristine
  - High quality data are developed through application of data quality objectives
  - Objective data screens are used to refine reference
  - It is critical the final data set accurately reflects the reference condition, including the assessment endpoints
- States have concerns with applying the reference condition approach when there are not many uncompromised sites. There are solutions for regions with heavily impacted sites.
- Defining acceptable levels of uncertainty (i.e., what is the correct percentile to choose?) should be informed by data.
- The reference condition approach is scientifically defensible when supported with appropriate rationales and data.